DEPARTMENT OF

Drainage and Waters

STATE OF MINNESOTA

E. V. WILLARD, Commissioner

DRAINAGE AREAS OF MINNESOTA STREAMS AND METHOD OF ESTIMATING PROBABLE FLOOD FLOWS

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CONTENTS.

INTRODUCTION.

The problem of controlling floods, developing water powers, furnishing ample water supply for municipal consumption, designing adequate culverts and bridges, providing sufficient capacity for drains and all kindred problems begin with run-off. A knowledge therefore, of the behavior of that portion of the water supplied by precipitation which finds its way to the streams which carry it to lower elevations, is fundamental to an intelligent consideration of practically every problem with which the hydraulic and drainage engineer is confronted.

In instances where the rate and volume of run-off has been observed by actual measurement of streams, and such observations have covered a sufficiently long period of years to include fairly dependable extremes of high and low discharges, intelligent conclusions may be drawn from such data alone, even if the engineer's knowledge of climatological phenomenon and physical characteristics of the area which furnishes the run-off is meagre. Unfortunately such records of flow on streams within or affecting Minnesota are rare, and with the exception of a few of the larger streams, may be said to be entirely lacking. This is particularly true of all of the smaller streams, the treatment of which so often becomes the duty of the engineers concerned with the design of drainage outlets and with providing culvert and bridge capacities for maximum flood flow.

In the absence of actual dependable measurements of flow, conclusions and designs must be based on climatological data combined with a knowledge of the physical characteristics of the water-shed from which the run-off is supplied. Climatological data includes records of precipitation (rain and snow-fall), temperature, evaporation, humidity and wind movement. The physical characteristics of the water-shed of which knowledge should be had, are extent and shape of area, topography, nature of soil, vegetation and general slope of area towards the outlet channel. The data compiled by the United States Weather Bureau offers an authentic source of information concerning weather conditions, and are made available in convenient form through the Bureau's monthly and annual publications.

Of the elements which go to make up the physical characteristics of the water-shed, undoubtedly the most important one, and one which always bears a decided relation to the rate and volume of run-off, is the extent of area which contributes the water. Topography, nature of soil, vegetal covering, slope and shape of area, while all of sufficient importance to merit careful consideration, are factors, the effects on run-off of which usually permit of a more general interpretation. They are largely peculiar to each water-shed, and therefore variable, and are usually given their proper weight by the exercise of judgment based on general visual observations of these factors which prevail. A knowledge of the approximate area of the drainage basin, however, has been recognized as essential, which fact is made manifest by the prominence this factor is given in all formulas proposed for the determination of rate and volume of run-off when actual measurements are lacking, and when weather phenomenon and nature of water-shed must be made the basis of conclusions.

It is with a view of furnishing a more ready reference to the extent of the drainage areas of the principal streams within and affecting Minnesota and their main tributaries, as well as to present a simple formula and method for use of engineers in estimating probable maximum flows which may be expected in such streams, that this pamphlet has been prepared and published.

The base map from which the areas within Minnesota have been determined is one which has been prepared by the department for the exclusive purpose of showing the water resources of the state. This map is drawn on a scale of 1/3 inch = 1 mile,

the original being made up by actually reproducing all the streams, lakes and sub-division lines from the original township plats prepared by the United States Land Office. The several drainage basins were outlined by pencil on this map and their areas subsequently determined by the use of the planimeter. The areas thus determined were checked against as many other maps and sources of information as were conveniently obtainable in order to discover any gross errors that might have crept in. The maps accompanying "Report on Drainage and Prevention of Over-flow in the Valley of the Red River of the North" by the United States Bureau of Public Roads, were used in checking areas affecting the Red River of the North. The standard topographic quadrangle maps of the United States Geological Survey offered a valuable source of information on the limited areas for which they are available. The names of the streams given in the "Report of Water Resources Investigations of Minnesota, 1909-1912" by the former Minnesota State Drainage Commission under the caption "Gazeteer of Minnesota Streams" furnished largely the basis from which the streams, the areas of which are given herein, have been selected. Areas of portions of drainage basins located outside of the boundaries of Minnesota, referred to herein, have been derived from state maps and other information that could be obtained. The state has been divided into the three major drainage basins which affect it—Mississippi, Hudson Bay and Lake Superior. All areas given in Table I are in order of their outletting into the principal channels beginning at the source and continuing to the mouth.

ACKNOWLEDGMENTS.

The work of arranging and determining the drainage areas shown in Table I has been done by W. S. Olson, office engineer of the department organization, assisted by G. E. Coons, deputy commissioner. The analysis of flood flow formulas and the derivation of the curve shown on Figure I, and Tables II, III and IV are contributions of A. F. Meyer in his capacity as consulting engineer for the department and C. M. Halseth, assistant engineer.

ESTIMATING FLOOD FLOW OF STREAMS.

The multiplicity of flood flow formulas which have been presented by different engineers for various parts of the country leave the Minnesota engineer somewhat in doubt as to which formula is best adapted to the conditions prevailing in this state. A comparison of the various formulas leads to the conclusion that there is not as much difference between them as might at first appear.

Although many of the formulas contain only one variable, namely, the area of the drainage basin, it does not follow that area is the only factor to which these formulas give consideration.

In general, it may be stated that the maximum rate of run-off from a drainage basin will be produced by the maximum rainfall which may be expected within the time required for water from the remotest portion of the basin to reach the point on the stream under consideration; that is, the rate of rainfall causing maximum flood run-off from a given basin depends upon the time of concentration of the run-off. The time of concentration in turn depends upon the character and size of the drainage basin—therefore the rate of rainfall to be used in determining flood run-off varies with the drainage area.

Our studies of the various flood flow formulas and of floods on Minnesota and Wisconsin streams have developed the following facts:

As a rough approximation, the peak discharge in cubic feet per second, during a flood, is about double the average discharge in cubic feet per second.

The relation between the peak discharge and the average 24-hour discharge is given by Fuller's Table 1, page 568, Trans. A. S. C. E. 1914, quoted on page 344, Elements of Hydrology, by Meyer.

The rate of rainfall to be used for gently rolling country in Minnesota, in inches per hour, equals about 30 divided by the area in acres, raised to the .4 power, or:

$$R = \frac{30}{A^{.4}}$$

The principal effect of the slope of the water-shed is upon the time of concentration of the run-off, which in turn affects the rate of rainfall to be used, and in this manner the slope indirectly affects the flood flow very materially.

The frequency of flood flows of various magnitudes on a given stream is very similar to the frequency of various rates of intense precipitation on the drainage basin. For Minnesota conditions, the frequency of intense rainfall, as given in Meyer's Elements of Hydrology, for cities within Group 3, page 183, with a slight modification to conform to the frequency of excessive daily precipitation as shown on page 123, substantially corresponds to the frequency of floods of given magnitude, as developed by Fuller in Trans. A. S. C. E. 1914, page 568, and briefly summarized on page 344, Table 39, of Meyer's Hydrology.

The general formula for flood flow applicable to Minnesota conditions reduces to:

$$Q = 100A^{.6}$$

This formula represents the maximum rate of discharge in cubic feet per second which may be expected, on an average, once in twenty-five years, from ordinary, gently rolling drainage basins having an area "A" in square miles.

For convenience, the values of "$A^{.6}$" are given in Table II, and on three graphs in Fig. 1. If desired, these values may be plotted to larger scale graphs for office use in solving for "Q".

For other frequencies than once in twenty-five years, multiply the coefficient 100 by the values given in Table III.

For drainage basins of different slope and character of soil and topography, multiply the coefficient 100 as modified for frequency by the proper coefficient as given in Table IV.

ESTIMATING TOTAL RUN-OFF OR YIELD OF DRAINAGE BASINS.

The engineer is often called upon to estimate the yield or total run-off from a drainage basin during the several months of the year. When no discharge records are available for the given stream, reasonably good estimates can be made from rainfall and other physical data by the method developed by Meyer and described by him in Trans. A. S. C. E. 1916, pages 1056 to 1224, and in his "Elements of Hydrology," Chapter XI, pages 410 to 436.

According to Meyer's method, the monthly evaporation and transpiration losses are computed for the given basin and are subtracted from the monthly precipitation. The precipitation minus losses is available for run-off. The distribution of this run-off through the several months of the year is a more involved computation. Each month's precipitation minus losses is divided into surface run-off, surface storage, soil storage and subsoil storage. The water which percolates into the subsoil furnishes the seepage flow of the stream. The seepage flow plus the surface run-off during a given month gives the total run-off for that month.

The more study and experience that can be brought to bear on the problem, the more accurate will be the results obtained. The published discussions of the method to which reference has already been made should be carefully studied by everyone attempting to utilize it.

ILLUSTRATION OF THE USE OF FORMULA AND TABLES

EXAMPLE NO. 1.

Problem: Required to determine the size and capacity of a bridge to be constructed across the Warroad River near its mouth in order to pass the maximum flow to be expected on an average once in 100 years.

Solution: $Q = 100A^{.6}$

Where Q = maximum flow to be expected within the given time,
A = Area of watershed.

From Table I we find the area of the Warroad River, A, to be 220 square miles.

The judgment of the engineer must be relied on to select the classification under Run-off Coefficients found in Table IV applicable to the Warroad River drainage area, but for the purpose of this example it will be placed under classification 4, loam soil. For this condition we find the coefficient to be .70.

Under Table III, Frequency Coefficients, we find the coefficient for a flood of a magnitude to be expected once in 100 years to be 1.4.

Applying these coefficients and factors to the formula and solving, we have

$$Q = 100 \times 220^{.6} \times .70 \times 1.4$$

From curve, Figure 1,

$$220^{.6} = 25$$

Whence $Q = 100 \times 25 \times .70 \times 1.4$

Q = 2,450 cubic feet per second or the maximum flood flow for which bridge capacity should be provided.

EXAMPLE NO. 2.

Problem: Required to determine the maximum rate of flow to be expected on an average once in 25 years at or near the outlet of the Crow River.

Solution: $Q = 100A^{.6}$

A glimpse at the map shows that the Crow River receives its water from two separate and independent streams, the North Branch and the South Branch, the two joining at or near Rock-

ford to form the main stream. Sound judgment at once suggests that each of these tributaries should be treated separately for a maximum discharge to be expected in each at the point of confluence.

From Table I we find the area of the North Branch of the Crow River to be 1,217 square miles.

For the purpose of this illustration the area will be placed under classification 3, Clayey Soil, of Run-off Coefficients, Table IV. For this condition we find the coefficient to be .75.

Under Table III, Frequency Coefficients, we find for floods of a magnitude to be expected once in 25 years the coefficient to be 1.00.

Applying these coefficients and solving

$$= 100 \times 1{,}217^{.6} \times .75 \times 1.00$$

From curve, Figure 1,

$$1{,}217^{.6} = 71$$

Whence

$$Q = 100 \times 71 \times .75 \times 1.00$$

$Q = 5{,}325$ cubic feet per second or the maximum flow that may be expected in the North Branch of the Crow River at its mouth on an average once in 25 years.

Giving the South Branch of the Crow River the same treatment:—

From Table I we find the area of the South Branch of the Crow River to be 1,554 square miles.

From Curve, Figure 1,

$$1{,}544^{.6} = 82$$

Applying the same Frequency Coefficient and Run-off Coefficient from Table III and Table IV respectively as in the case of the North Branch and solving,

$= 100 \times 82 \times .75 \times 1.00$

$= 6{,}150$ cubic feet per second, the maximum flow which may be expected at the mouth of the South Branch of the Crow River on an average of once in 25 years.

Adding the discharges of the two branches gives a maximum flow in the Crow River below the junction of the North and South Branches of 11,475 cubic feet per second.

TABLE I.

AREAS IN SQUARE MILES OF THE PRINCIPAL DRAINAGE BASINS IN MINNESOTA AND ADJACENT TRIBUTARY TERRITORY.

RESUME.

MAJOR BASINS

	Area, Square Miles
1. MISSISSIPPI RIVER DRAINAGE BASIN:	
Area above the outlet of the Minnesota River	19,888
Area below the outlet of the Minnesota River, exclusive of the Minnesota, Missouri, Des Moines and Red Cedar River basins	9,447
Minnesota River:	
Tributary area within Minnesota	14,262
Tributary area within South Dakota	1,620
Tributary area within Iowa	655
Area within Minnesota draining through the Des Moines and Red Cedar Rivers	2,663
Area within Minnesota draining through the Missouri River	1,799
2. HUDSON BAY DRAINAGE BASIN:	
Rainy River, area within Minnesota	10,454
Red River of the North:	
Tributary area within Minnesota (including the Roseau River)	17,388
Tributary area within North and South Dakota	17,952
Tributary area within Canada, draining into Roseau River at points within Minnesota	2,042
3. LAKE SUPERIOR DRAINAGE BASIN:	
Pigeon River:	
Tributary area within Minnesota	227
Tributary area within Canada	401
Areas within Minnesota directly tributary to Lake Superior	5,658
Total Areas of the Major Basins located within Minnesota	81,986

MISSISSIPPI RIVER DRAINAGE BASIN.

SUMMARY

	Area, Square Miles
Total Mississippi River drainage area including 1,620 square miles within South Dakota, and 655 square miles in Iowa, but exclusive of area within Wisconsin	50,334
Total area of the Mississippi River drainage basin within Minnesota	48,059

MISSISSIPPI RIVER.

NAMES OF THE TRIBUTARY AREAS

Grant Creek			125
Yellow Head River			177
Turtle River			240
Third River			137
Pigeon River			105
Area bordering on the Mississippi River above the Leech Lake River outlet			750
Total area above the Leech Lake River outlet			1,534
Leech Lake River			1,246
Steamboat River		116	
Kabekona River		123	
Shingobi Creek		26	
Boy River		429	
Laura Brook	31		
Swift River	30		
Bear River		27	
Area bordering on the Leech Lake River above the Leech Lake outlet			464
Ball Club River			49
Deer River			128
Vermillion River			37
Prairie River			446
Area bordering on the Mississippi River between the Leech Lake River outlet and the Swan River outlet			327
Total area above the outlet of the Swan River			4,231
Swan River			330
Sandy River			423
Savanah River		48	
Prairie River above Sandy Lake		256	
Tamarack River	119		
Area bordering on the Mississippi River between the Swan River outlet and the Willow River outlet			112
Total area above the Willow River outlet			5,096
Willow River			483
Hill River		86	
Morrison Brook	37		
Moose River		89	
White Elk Brook		44	

	Area, Square Miles		
Rice River			356
Dam Brook		52	
Sisabagama Creek			45
Mud River			106
Little Willow River			87
Dean Brook			23
Area bordering on the Mississippi River between the Willow River outlet and the Pine River outlet			135
Total area above the Pine River outlet			6,331
Pine River			802
Ada Brook		71	
Daggett Brook		141	
Washburn Brook	38		
Little Pine River		140	
Rabbit River			39
Sand Creek			23
Area bordering on the Mississippi River between the Pine River outlet, and the Crow Wing River outlet			121
Total area above the Crow Wing River outlet			7,316
Crow Wing River			3,668
Shell River		548	
Straight River	269		
Fish Hook River	191		
Blueberry River	44		
Swamp River		67	
Cat River		50	
Little Swamp Creek		9	
Beaver Creek		13	
Farnham Creek		53	
Leaf River		795	
Bluff Creek	78		
Oak Ridge Creek	31		
Wing River	184		
Red Eye River	196		
Partridge River		91	
Swan Creek		43	
Mosquito Creek		51	
Long Prairie River		817	
Calamas Creek	40		
Belle River	56		
Eagle Creek	80		
Turtle Creek	10		
Moran Brook	60		
Fish Trap River	81		
Seven Mile Creek		27	
Pillager Creek		12	

	Area, Square Miles		
Gull River		291	
Stoney Brook	43		
Home Brook	57		
Nokasippi River			228
Daggett Brook		56	
Fletcher Boundary Creek			44
Little Elk River			135
Pike Creek			32
Swan River			115
Two Rivers			153
South Two Rivers		105	
North Two Rivers	46		
Spunk River			56
Area bordering on the Mississippi River between the Crow Wing River outlet and the Platte River outlet			151
Total area above the Platte River outlet			11,898
Platte River			313
Skunk River	186		
Little Rock River			102
Watab River			85
Area bordering on the Mississippi River between Platte River outlet and the Sauk River outlet			62
Total area above the Sauk River			12,460
Sauk River			860
Adley Creek		88	
Ashley Creek		116	
Plum Creek			46
St. Augusta Creek			8
Clearwater River			181
Silver Creek			52
Elk River			607
Meyhew Creek		60	
Rice Creek		53	
Snake River		18	
St. Francis River		220	
Battle Brook	12		
Tibbitts Brook		45	
Area bordering on the Mississippi River between the Snake River outlet and the Crow River outlet			212
Total area above the Crow River outlet			14,426
Crow River			2,838
Crow River (north branch)		1,217	
Skunk River	26		
Crow River (middle branch)	310		
Jewett Creek	38		
Sucker Creek	35		

	Area, Square Miles		
Twelve Mile Creek	65		
Crow River (south branch)		1,554	
Buffalo Creek	670		
Pioneer Creek		54	
Rum River			1,575
Borden Brook		18	
Bradbury Brook		20	
Stoney Brook		8	
Whitney Brook		8	
Tibbitts Brook		40	
Mike Dreur Brook		12	
O'Neill Brook		12	
Bandell Brook		17	
Bogus Brook		25	
Rum River (west branch)		175	
Estes Brook	105		
Green Lake Brook		28	
Stanchfield Creek		25	
Seely Brook		60	
Cedar Creek		96	
Trott Brook		53	
Elm Creek			86
Rush Creek		32	
Coon Creek			113
Rice Creek			150
Shingle Creek			335
Bassett Creek			46
Minnehaha Creek			206
Area bordering on the Mississippi River between the Crow River outlet and the Minnesota River outlet			113
Total area above the Minnesota River outlet			19,888
Minnesota River			16,537
(For details of tributary areas of the Minnesota River, see page 17)			
Area bordering on the Mississippi River between the Minnesota River outlet and the St. Croix River outlet			272
Total area above the St. Croix River			36,697
St. Croix River			3,254
(For details of tributary areas to St. Croix River in Minnesota, see page 19)			
Vermillion River			261
Area bordering on the Mississippi River between the St. Croix River outlet, and the Cannon River outlet			80
Total area above the Cannon River			40,292
Cannon River			1,440
Little Cannon River		16	
Devil Creek		21	

	Area, Square Miles	
Mackenzie Creek		13
Straight River		465
Crane Creek	107	
Wolf Creek		49
Heath Creek		34
Prairie Creek		103
Little Cannon River		98
Chub Creek		20
Trout Brook		22
Belle Creek		92
Wells Creek		77
Area bordering on the Mississippi River between the Cannon River outlet and the Zumbro River outlet		168
Total area above the Zumbro River outlet		41,977
Zumbro River		1,377
Zumbro River (south branch)	810	
Zumbro River (middle branch)	399	
Zumbro River (north branch)	240	
Whitewater River		320
Rollingstone Creek		128
Rollingstone Creek (south branch)	55	
Rollingstone Creek (west branch)	55	
Pine Creek		64
Area bordering on the Mississippi River between the Zumbro River outlet and the Root River outlet		149
Total area above the Root River outlet		44,015
Root River		1,662
Mill Creek	37	
Root River (middle branch)	218	
Deer Creek	60	
Trout Creek	53	
Root River (south branch)	291	
Rush Creek	108	
Money Creek	219	
Root River (south fork)	290	
Riceford Creek	69	
Silver Creek	26	
Crystal Creek	12	
Thompson Creek	50	
Winnebago Creek		90
Area bordering on the Mississippi River between the Root River outlet and the Minnesota–Iowa State Boundary		105
Total area above the Minnesota–Iowa State Boundary draining directly into the Mississippi River		45,872
Areas in Minnesota draining into the Mississippi River at ponts outside of Minnesota (see details of tributary areas)		4,462

MISSISSIPPI RIVER DRAINAGE BASIN.

MINNESOTA RIVER.

SUMMARY

	Area, Square Miles
Total Minnesota River drainage area	16,537
Tributary area within Minnesota	14,262
Tributary area within South Dakota	1,620
Tributary area within Iowa	655

NAMES OF THE TRIBUTARY AREAS

Area within Minnesota bordering on Big Stone Lake and the Minnesota River above the outlet of the Yellow Bank River		252
Area within South Dakota bordering on Big Stone Lake and tributary to the Minnesota River above the outlet of the Yellow Bank River		920
Stony Run		108
Yellow Bank River:		
Tributary area within Minnesota		144
Tributary area within South Dakota		415
Total tributary area		559
Area bordering on the Minnesota River between the Yellow Bank River outlet and the Pomme de Terre River outlet		109
Total area above the Pomme de Terre River outlet		1,948
Pomme de Terre River		961
Mud Creek	148	
Area bordering on the Minnesota River between the Pomme de Terre River outlet and the Lac qui Parle River outlet		118
Total area above the Lac qui Parle River outlet		3,027
Lac qui Parle River:		
Tributary area within Minnesota		768
Tributary area within South Dakota		285
Total tributary area		1,053
Lac qui Parle River (east branch)	105	
Canby Creek	93	
Florida Creek	82	
Area bordering on the Minnesota River between the Lac qui Parle River outlet and the Chippewa River outlet		110
Total area above the Chippewa River		4,190
Chippewa River		1,893
Shakopee Creek	346	
Chippewa River (east branch)	423	
Little Chippewa River	230	

	Area, Square Miles	
Stony Run		176
Hawk Creek		531
Chetamba Creek	152	
Area bordering on the Minnesota River between the Chippewa River outlet and the Yellow Medicine River outlet		70
Total area above the Yellow Medicine River outlet		6,860
Yellow Medicine River		550
Area bordering on the Minnesota River between the Yellow Medicine River outlet and the Redwood River outlet		181
Total area above the Redwood River		7,591
Redwood River		702
Three Mile Creek	78	
Beaver Creek		249
Area bordering on the Minnesota River between the Redwood River outlet and the Cottonwood River outlet		561
Total area above the Cottonwood River		9,103
Cottonwood River		1,200
Sleepy Eye Creek	282	
Highwater Creek	102	
Dutch Charlie's Creek	78	
Plum Creek	77	
Area bordering on the Minnesota River between the Cottonwood River outlet and the Little Cottonwood River outlet		11
Total area above the Little Cottonwood River outlet		10,314
Little Cottonwood River		255
Nicollet Creek		175
Minneopa Creek		62
Area bordering on the Minnesota River between the Little Cottonwood River outlet and the Blue Earth River outlet		65
Total area above the Blue Earth River outlet		10,871
Blue Earth River:		
Tributary area within Minnesota		3,183
Tributary area within Iowa		655
Le Sueur River	938	
Maple River	272	
Cobb River	214	
Little Cobb River	80	
Boot Creek	54	
Watonwan River	780	
Perch Creek	107	
Watonwan River (south branch)	220	
Chain River, Elm Creek	283	

	Area, Square Miles	
Center Creek	113	
Lily Creek	31	
South Creek	84	
Blue Earth River (east branch)	310	
Jones Creek	130	
Shanaska Creek		51
Cherry Creek		57
Le Sueur Creek		128
Little Le Sueur Creek	46	
Rush River		300
High Island Creek		183
Bevens Creek		120
Carver Creek		72
Sand Creek		267
Raven Stream	46	
Porter Creek	84	
Credit River		90
Nine Mile Creek		40
Area bordering on the Minnesota River between the Blue Earth River outlet and the Mississippi River		520

MISSISSIPPI RIVER DRAINAGE BASIN.

ST. CROIX RIVER*

SUMMARY

Total St. Croix River drainage area	7,290
Tributary area within Minnesota	3,254

NAMES OF TRIBUTARY AREAS WITHIN MINNESOTA

Spruce River	13
Area bordering on the St. Croix River between the Spruce River outlet and the Tamarack River outlet	8
Total area above the Tamarack River outlet	21
Tamarack River	166
Area bordering on the St. Croix River between the Tamarack River outlet and the Crooked Creek outlet	5
Total area above the Crooked Creek outlet	192
Crooked Creek	78
Area bordering on the St. Croix River between the Crooked Creek outlet and the Sand River outlet	9
Total area above the Sand River outlet	279
Sand River	139
Area bordering on the St. Croix River between the Sand River outlet and the Bear Creek outlet	1
Total area above the Bear Creek outlet	419

		Area, Square Miles
Bear Creek		44
Area bordering on the St. Croix River between Bear Creek outlet and the Kettle River outlet		2
Total area above the Kettle River outlet		465
Kettle River		1,030
Grindstone River	102	
Pine River	103	
Little Pine River	24	
Willow River	116	
Moose River	161	
Partridge River	14	
Split Rock River	86	
Otter Brook	18	
Dead Moose River	24	
Moose Horn River	43	
Area bordering on the St. Croix River between the Kettle River outlet and the Snake River outlet		14
Total area above the Snake River outlet		1,509
Snake River		936
Mission Creek	15	
Pokegema Creek	88	
Mud Creek	70	
Rice Creek	23	
Groundhouse River	138	
Ann River	70	
Knife River	89	
Cowan Brook	10	
Chester Brook (Little Snake River)	16	
Area bordering on the St. Croix River between the Snake River outlet and Goose Creek outlet		135
Total area above Goose Creek outlet		2,580
Goose Creek		67
Area bordering on the St. Croix River between the Goose Creek River outlet and the Sunrise River outlet		8
Total area above the Sunrise River outlet		2,655
Sunrise River		307
Area bordering on the St. Croix River between the Sunrise River outlet and Brown Creek outlet		170
Brown Creek		16
Area bordering on the St. Croix River between the Brown Creek outlet and Bolles Creek outlet		44
Total area above Bolles Creek outlet		3,192
Bolles Creek		18

	Area, Square Miles
Area within Minnesota bordering on the St. Croix River between the Bolles Creek outlet and the mouth of the St. Croix River	44
TOTAL DRAINAGE AREA OF THE ST. CROIX RIVER WITHIN MINNESOTA	3,254

*Note—No attempt has been made to determine extent of tributary areas located within the State of Wisconsin.

MISSISSIPPI RIVER DRAINAGE BASIN.

AREAS WITHIN MINNESOTA DRAINING INTO THE MISSISSIPPI RIVER AT POINTS OUTSIDE OF MINNESOTA.

SUMMARY

Total area within Minnesota draining into the Mississippi River outside of Minnesota		4,462
Missouri River Drainage Basin	1,799	
Areas along the Iowa boundary draining through Iowa directly into the Mississippi River	2,663	

NAMES OF TRIBUTARIES AND THEIR AREAS WITHIN MINNESOTA DRAINING DIRECTLY INTO THE MISSISSIPPI RIVER WITH OUTLETS IN IOWA

Iowa River (upper reaches)		192
Little Cedar River		71
Cedar River		957
Shell-rock River	322	
Woodbury Brook	55	
Rose Creek	93	
Turtle Creek	184	
Des Moines River		1,443
Des Moines River (east branch)	126	
Herron Lake outlet	507	
Jack Creek	240	
Okabena Creek	171	

NAMES OF TRIBUTARIES WITHIN MINNESOTA DRAINING INTO THE MISSISSIPPI RIVER THROUGH THE MISSOURI RIVER

Rock River		872
Little Rock River	120	
Kanaranzi Creek	186	
Elk Creek	58	
Champepedan Creek	83	
Chanarambic Creek	74	

	Area, Square Miles	
Big Sioux River		751
Beaver Creek	138	
Split Rock Creek	440	
Pipestone Creek	68	
Flandreau Creek	105	
Area draining into Big Sioux River north of Flandreau Creek		63
Little Sioux River		113

HUDSON BAY DRAINAGE BASIN.

SUMMARY

RED RIVER OF THE NORTH

Total area		37,382
Tributary area within Minnesota, including the Roseau River	17,388	
Tributary area in North and South Dakota	17,952	
Tributary area in Canada	2,042	

RAINY RIVER

Total area within Minnesota		10,454
Total Hudson Bay Drainage Basin		47,836

RED RIVER OF THE NORTH

NAMES OF TRIBUTARIES

Areas within Minnesota bordering on Lake Traverse, between Browns Valley and the Mustinka River outlet		74
Mustinka River, total		831
Mustinka River above outlet of Five Mile Creek	199	
Five Mile Creek	150	
Twelve Mile Creek	368	
Area within Minnesota bordering on Lake Traverse, and the Bois de Sioux River between the Mustinka River outlet and the outlet of the Rabbit River		73
Area within Minnesota above the Rabbit River outlet		978
Rabbit River		298
Area within Minnesota bordering on the Bois de Sioux River between the Rabbit River outlet and the Otter Tail River outlet		58
Area within North and South Dakota tributary to Lake Traverse and the Bois de Sioux River above the outlet of the Otter Tail River		553
Area within Minnesota above the outlet of the Otter Tail River at Breckenridge		1,334
Total drainage area above Breckenridge		1,887

	Area, Square Miles	
Otter Tail River		1,824
Dead River	104	
Toad River	110	
Pelican River	468	
Area within Minnesota bordering on the Red River between the outlet of the Otter Tail River and Fargo		408
Area within North Dakota bordering on the Red River between the outlet of the Otter Tail River and Fargo		84
Wild Rice River (North Dakota)		2,169
Area within Minnesota above Fargo		3,566
Total area above Fargo		6,372
Area within Minnesota bordering on the Red River between Fargo and the outlet of the Buffalo River		57
Buffalo River		1,124
Buffalo River (south branch)	444	
Deerhorn Creek	122	
Whiskey Creek	80	
Willow River	160	
Area within Minnesota bordering on the Red River between the outlet of the Buffalo River and the Minnesota Wild Rice River outlet		40
Area in North Dakota bordering on the Red River between Fargo and the outlet of the Elm River		192
Sheyenne River (North Dakota)		7,336
Elm River (North Dakota)		468
Area within Minnesota above the outlet of the Minnesota Wild Rice River		4,787
Total drainage area above the outlet of the Minnesota Wild Rice River		15,589
Wild Rice River, Minnesota, total area		1,510
White Earth River	199	
Wild Rice (south branch)	357	
Area within Minnesota bordering on the Red River between the outlet of the Minnesota Wild Rice River and the Marsh River outlet		80
Area within North Dakota bordering on the Red River between the outlet of the Elm River and the Goose River outlet		51
Goose River (North Dakota)		1,314
Area within Minnesota above the outlet of the Marsh River		6,377
Total area above the outlet of the Marsh River		18,544
Marsh River		286
Area within Minnesota bordering on the Red River between the outlet of the Marsh River and the Sand Hill River outlet		59
Sand Hill River		544

			Area, Square Miles
Area within Minnesota bordering on the Red River between the outlet of the Sand Hill River and the Red Lake River outlet			40
Area within North Dakota bordering on the Red River between the Goose River outlet and Grand Forks			481
Total area above Grand Forks			19,957
Red Lake River			5,709
Tamarac River		289	
Shotley Brook		65	
Battle River		162	
Black Duck River		269	
Hay Creek		42	
Mud River		64	
Pike Creek		24	
Big Rock Creek		30	
Sandy River		95	
Area of Upper and Lower Red Lakes		440	
Area bordering on the Red Lakes		405	
Area above the outlet of Lower Red Lake		1,885	
Area bordering on the Red Lake River between the outlet of Lower Red Lake and the Thief River outlet		482	
Total area above the Thief River outlet		2,367	
Thief River		1,168	
Moose River	282		
Area bordering on the Red Lake River between the Thief River outlet and the Clearwater River outlet		170	
Total area above the Clearwater River		3,705	
Clearwater River		1,294	
Badger Creek	147		
Lost River	612		
Poplar River	107		
Hill River	200		
Black River		145	
Area within Minnesota above Grand Forks			13,015
Area within Minnesota bordering on the Red River between the outlet of the Red Lake River and the Grand Marais River outlet			17
Grand Marais River			254
Area within North Dakota bordering on the Red Lake River between Grand Forks and the outlet of the Turtle River			139
Turtle River (North Dakota)			699
Area bordering on the Red River between the outlet of the Grand Marais River and the Snake River outlet			36
Forest River (North Dakota)			1,122
Area within Minnesota above the Snake River outlet			13,322
Total area above the Snake River outlet			27,933

	Area, Square Miles	
Snake River		991
Middle River	303	
Area within Minnesota bordering on the Red River between the Snake River outlet and the Tamarac River outlet		8
Area within North Dakota bordering on the Red River between the outlet of the Forest River and the Park River outlet		12
Tamarac River		520
Park River (North Dakota)		881
Area within Minnesota bordering on the Red River between the outlet of the Tamarac River and the Two Rivers outlet		263
Area within Minnesota above the Two Rivers outlet		16,104
Two Rivers		1,027
Area within Minnesota bordering on the Red River between the outlet of the Two Rivers and the International Boundary		27
Roseau River, within Minnesota		1,230
Area within North Dakota bordering on the Red River between the outlet of the Park River and the Pembina River outlet		454
Pembina River:		
Tributary area in North Dakota		1,994
Tributary area in Canada		2,042

HUDSON BAY DRAINAGE BASIN.

RAINY RIVER IN MINNESOTA*

NAMES OF TRIBUTARIES

Areas bordering the Gunflint Lakes to Cross River outlet		33
Cross River		88
Area bordering on Saganaga, Knife and Basswood Lakes from the outlet of Cross River to the outlet of the Kawishiwi River		400
Total area above the Kawishiwi River		521
Kawishiwi River		1,402
Beaver River	57	
Birch River (south fork Kawishiwi River)	26	
Dunka River	14	
Stony River	246	
Burntside River	142	
Isabella River	333	
Isabella River (south branch)	60	
Area bordering on the Rainy River between the Kawishiwi River outlet and the Loon River outlet		441

	Area, Square Miles		
Total area above the Loon River			2,364
Loon River			32
Area bordering on the Rainy River between the Loon River outlet and the Vermillion River outlet			39
Total area above the Vermillion River			2,435
Vermillion River			1,028
Armstrong River		17	
East Two Rivers		10	
West Two Rivers			20
Pike River		199	
Pelican River		196	
Elbow River	48		
Echo Lake Outlet		102	
Area bordering on the Rainy River between the Vermillion River outlet and the Namekin River outlet			49
Namekin River			34
Area bordering on the Rainy River between the Namekin River outlet and the Moose River outlet			15
Total area above the Moose River outlet			3,561
Moose River			48
Ash River			146
Black Duck River		34	
Area bordering on Namekin and Rainy Lakes between the Moose River outlet and the Rat Root River outlet			265
Total area above the Rat Root River outlet			4,020
Rat Root River			291
Area bordering on the Rainy River between the Rat Root River outlet and the Little Fork River outlet			73
Total area above the Little Fork River			4,384
Little Fork River			1,767
Beaver Creek		22	
Sturgeon River		504	
Bearskin River	172		
Willow River		69	
Net Lake River		191	
Beaver Brook		121	
Area bordering on the Rainy River between the Little Fork River outlet and the Big Fork River outlet			6
Total area above the Big Fork River outlet			6,157
Big Fork River			1,985
Bow String River (above Big Fork)		600	
Caldwell Brook		157	
Sturgeon River		312	
Area bordering on the Rainy River between the Big Fork River outlet and the Black River outlet			3
Total area above the Black River outlet			8,145

	Area, Square Miles
Black River	400
Area bordering on the Rainy River between the Black River outlet and the Rapid River outlet	125
Total area above the Rapid River outlet	8,670
Rapid River	900
Area bordering on the Rainy River between the Rapid River outlet and the Beaudette River outlet	32
Total area above the Beaudette River	9,602
Beaudette River	96
Area bordering on the Rainy River between the Beaudette River outlet and the Winter Road River	21
Total area above the Winter Road River	9,719
Winter Road River	180
Area bordering on the Rainy River between the outlet of the Winter Road River and the mouth of the Rainy River	37
Total area in Minnesota above the mouth of the Rainy River	9,936
Area in Minnesota bordering on Lake of the Woods between the mouth of the Rainy River and the Warroad River outlet	244
Warroad River	220
Area in Minnesota bordering on Lake of the Woods between the outlet of the Warroad River and the International Boundary	54
TOTAL RAINY RIVER DRAINAGE AREA IN MINNESOTA	10,454

*No attempt has been made to determine extent of areas tributary to Rainy River, located within the Dominion of Canada.

LAKE SUPERIOR DRAINAGE BASIN.

SUMMARY

Total Lake Superior drainage area, including the Pigeon River tributaries in Canada (401 square miles)	6,259
Pigeon River, total area within Minnesota	227
Pigeon River, total drainage area	628

NAMES OF THE TRIBUTARIES

Pigeon River (including the Canadian tributaries)	628
Area within Minnesota bordering on South, Rose, Rove, Mountain, Moose and North Fowl Lakes	88
Pine River	25
Area within Minnesota bordering on South Fowl Lake between the Pine River outlet and the Stump River outlet	2
Stump River	18
Portage Brook	13

	Area, Square Miles		
Area within Minnesota bordering on the Pigeon River between the Portage Brook outlet and the Missaieh River outlet			2
Missaieh River			49
Area within Minnesota bordering on the Pigeon River between the Missaieh River outlet and Lake Superior			30
Total drainage area of Pigeon River within Minnesota			227
Nemadji River			243
Net River		68	
Black Hoof Creek		45	
St. Louis River			3,324
Partridge River		183	
Messaba Creek	38		
Embarrass River		180	
Mud Hen River		109	
Water Hen River	29		
Otter River		21	
East Two Rivers		54	
West Two Rivers		84	
East Swan River		236	
Stone River		40	
Sand Creek		62	
Whiteface River		496	
Bug Creek	40		
Paleface River	61		
Floodwood River		202	
East Savanah River		114	
Stoney Brook (Yellow Pine)		80	
Cloquet River		749	
Ushkabwakka River	58		
Boulder Creek	60		
Little Cloquet (Pequaywan Lake outlet)	62		
Cloquet River (west branch)	109		
White Pine Creek		39	
Otter Creek		43	
Midway Creek		58	
Area bordering on Lake Superior between the St. Louis River outlet and the Amity Creek outlet			67
Total area above the Amity Creek outlet			3,634
Amity Creek			10
Lester River			46
French River			22
Knife River			40
Stewarts River			38
Encampment River			19
Gooseberry River			94
Split Rock River			36

	Area, Square Miles	
Area bordering on Lake Superior in St. Louis and Lake Counties below Amity Creek outlet		197
Beaver Bay River		153
Baptism River		136
Manitou River		102
Two Island River		20
Cross River		78
Temperance River		212
Poplar River		167
Cascade River		89
Devil Track River		81
Greenwood River		16
Brule River		270
Poplar River	20	
Mawskiquawcawndu River		28
Area bordering on Lake Superior in Cook County		138
TOTAL LAKE SUPERIOR DRAINAGE AREA WITHIN MINNESOTA		5,858

TABLE II.

VALUES OF $A^{.6}$ FOR USE IN THE FORMULA $Q = 100A^{.6}$

A=Area in Square Miles	$A^{.6}$
100,000	1,000
70,000	807
40,000	577
30,000	486
20,000	381
10,000	251
7,000	203
4,000	145
3,000	122
2,000	96
1,000	63
700	51
400	36
300	31
200	24
100	16
70	13
40	9.1
30	7.7
20	6.0
10	4.0
7	3.2
4	2.3
3	1.9
2	1.5
1	1.00
0.7	.81
0.4	.58
0.3	.48
0.2	.38
0.1	.25
0.05	.17
0.01	0.06

VALUES OF $A^{.6}$
FOR USE IN THE FORMULA
$Q = 100 A^{.6}$

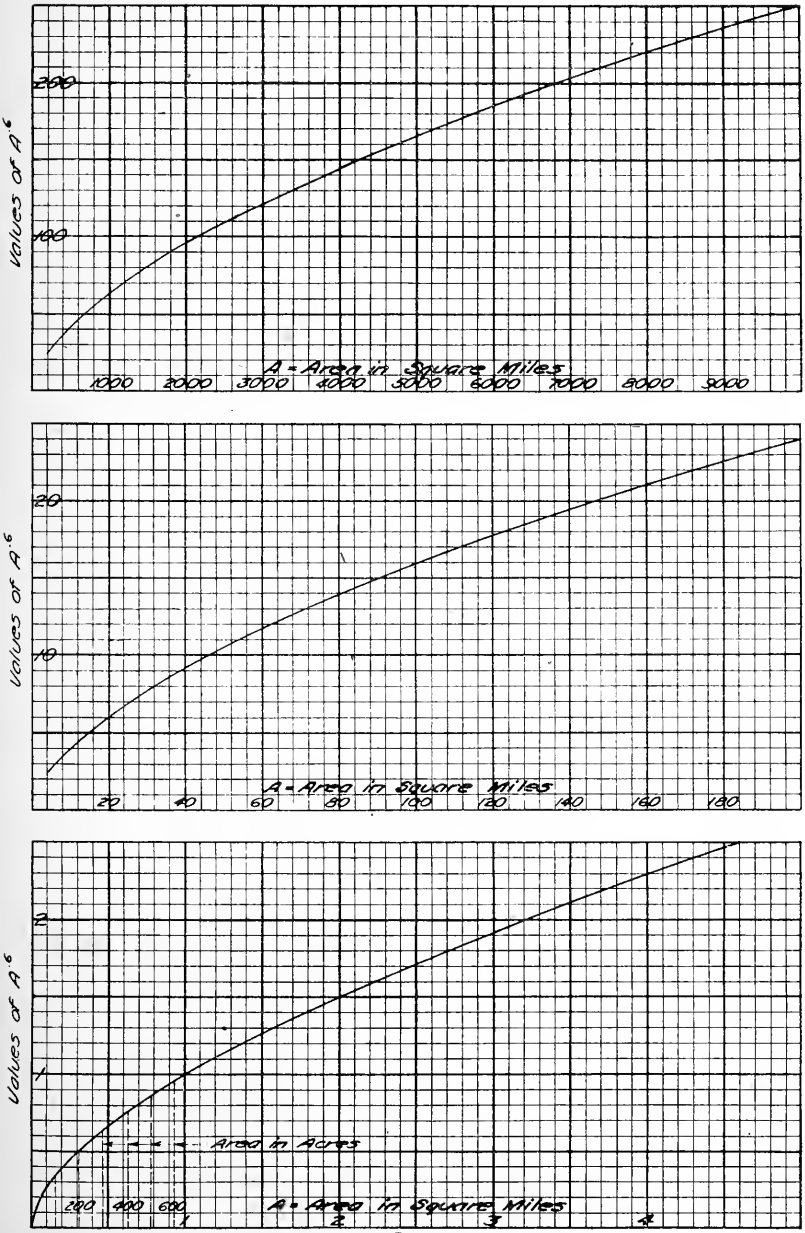

Fig.I.

TABLE III.

FREQUENCY COEFFICIENTS.

FLOOD FREQUENCY

For a flood of magnitude to be expected:	Coefficients
Once in 10 years	.85
Once in 25 years	1.00
Once in 100 years	1.40

TABLE IV.

RUN-OFF COEFFICIENTS.

CHARACTER OF DRAINAGE BASIN	Coefficients Soil Sandy	Loam	Soil Clayey
1. Very flat agricultural or timber land with some marshes and swamps	.35	.40	.50
2. Relatively flat agricultural or timber land with some marshes and ponds	.45	.50	.60
3. Gently rolling agricultural or timber land full of lakes, ponds and marshes connected by poorly defined water courses	.50	.60	.75
4. Relatively flat agricultural or timber land of fairly uniform slope, without lakes and ponds	.60	.70	.85
5. Slightly undulating agricultural or timber land without lakes or ponds; or distinctly rolling to hilly agricultural or timber land, with lakes and ponds	.70	.80	1.00
6. Gently rolling agricultural or timber land without lakes and ponds	.85	1.00	1.25
7. Distinctly rolling to hilly agricultural or timber land without lakes and ponds; or hilly agricultural or timber lands with steep slopes and lakes, ponds and marshes in valleys	1.10	1.50	2.00
8. Hilly agricultural or timber land with steep slopes barely admitting of cultivation; without lakes, ponds or marshes	2.25	3.00	4.00
9. Very hilly timber or brush-covered land, slopes too steep for cultivation; ravines and gullies with occasional small ponds or marshes	3.50	4.50	6.00
10. Very hilly timber or brush-covered land with some rock outcropping; ravines and gullies, and occasional small ponds or marshes	5.00	6.00	8.00
11. Very hilly to rugged country with much rock outcropping; scattered timber; occasional small ponds and marshes	9.00	10.00	12.00
12. Rugged to precipitous rocky country with practically no soil cover; small timber and brush; ravines and gullies; no lakes, ponds or marshes to retard runoff..	....	15.00	.....

Note—The available information on the subject does not indicate that forests have any material effect upon the extreme flood flow. They have a tendency to reduce the ordinary flood flow somewhat. In northern Minnesota forests have aggravated spring floods by retarding the melting of snow until warm April rains set in.

In determining the proper coefficient to use for a given drainage basin of diverse characteristics, subdivide the basin into approximately similar areas, select

the proper coefficient for each subdivision, and compute the average coefficient applicable to the entire area.

In general, it may be stated that lakes, ponds and marshes have a most pronounced retarding effect upon the runoff, resulting in low coefficients. A region may be hilly—even rocky—but between the hills and rock outcrops there may be lakes, ponds, marshes, bogs or muskegs, which greatly retard the flow of water to the main stream, even though the rainfall rapidly runs off from the hills into the valleys where the lakes, ponds and marshes lie. Drainage basins having a relatively uniform slope in one direction, particularly if deeply gullied, would require the use of large coefficients.

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